

**INVESTIGATION OF HUMAN THERMAL COMFORT BY OBSERVATING THE  
UTILIZATION OF OPEN AIR TERRACES IN CATERING PLACES  
– A CASE STUDY IN SZEGED**

L. ÉGERHÁZI, N. KÁNTOR, and Á. GULYÁS

*Department of Climatology and Landscape Ecology, University of Szeged, P.O.Box 653, 6701 Szeged, Hungary  
E-mail: egerhazililla@gmail.com*

**Summary** – The observation of the attendance of open-air terraces in restaurants, taverns and cafés provides an indirect way to estimate human reactions on thermal conditions. This paper reports the use of this human biometeorological survey method in two taverns located in Szeged (Hungary) in order to investigate the correlation between the relative attendance of outdoor places and the actual thermal conditions. The latter was quantified by the most popular human comfort index, Predicted Mean Vote (PMV), calculated by the bioclimate model RayMan from measured meteorological parameters influencing the thermal comfort sensation. In a 6 week long period, the relative attendance of the beer gardens of two taverns offering different microclimatic environments was observed in the afternoon hours (between 12 and 3 p.m.). The results proved that the attendance of outdoor places increases up to a specified PMV value, then decreases due to the intensified heat stress. This tendency is not only in harmony with the common human attitude, but also confirms the correctness of the applied bioclimate index (PMV).

**Key words:** attendance of open-air places, thermal comfort, Predicted Mean Vote

## 1. INTRODUCTION

Due to the rapid urbanization in our accelerated world, people spend less and less time in nature or even outdoors. This tendency enhances the role of public green areas e.g. city parks, and open-air terraces of catering places (e.g. restaurants, cafés) in the recreation and outdoor activities of the city-dwellers. Therefore, the question of urban thermal comfort, i.e. which thermal conditions are the most comfortable and enjoyable in urban environments, becomes of high importance.

City planning and development need to take into account the health and well-being of people living or working in urban areas. This task assumes bioclimatological approaches, the analysis of cities from a physiological point of view. One of the essential parts of urban bioclimatology is therefore the investigation of urban climate and weather conditions in order to estimate their influence on the human body (Jendritzky 1993).

Urban thermal conditions fundamentally determine the frequency and duration of outdoor activities, so the willingness to spend time outside can provide valuable information about the actual human thermal sensation. Catering places with indoor and outdoor parts can thus represent an optimal study area to investigate human thermal comfort by observing the spontaneous reaction of the guests to the changes of the thermal conditions, mainly through their preference of indoor or outdoor sites.

In this study, the relationship between a bioclimatic comfort index, the Predicted Mean Vote (PMV) and the relative attendance of the beer gardens of two local taverns was investigated. PMV was calculated by a bioclimate model (RayMan) using objective meteorological parameters (air temperature, air humidity, wind velocity, and global radiation). The relative attendance of the beer gardens, defined by the ratio of the number of guests outdoors and the total number of guests, was considered the subjective measure of human thermal comfort (Katzschner 2007, Nikolopoulou and Steemers 2003).

## 2. MATERIAL AND METHODS

### 2.1. Study area

The investigations took place in a Central-European city, Szeged (Southeast Hungary, 46°N, 20°E), where extensive urban climate research has been conducted for several years, mainly on the patterns of urban heat island (Unger et al. 2001, Unger 2006). In the last 10 years, research mainly focused on the bioclimatic conditions of the city compared to the rural areas (Unger 1999), as well as of some selected places in the downtown (Gulyás et al. 2006).

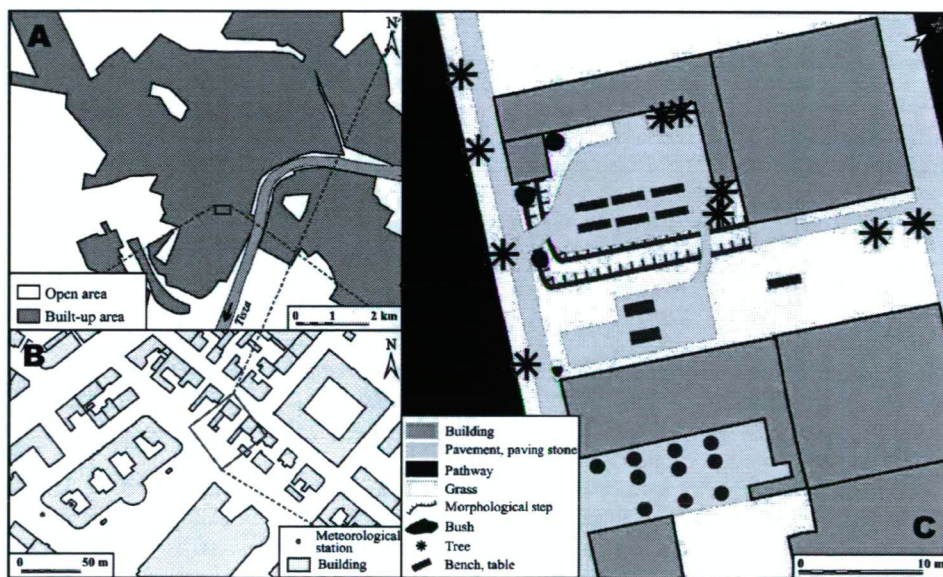


Fig. 1 The wider (A) and the closer (B) environments of the study area in Szeged, and its detailed map (C)

The two investigated catering places of the present study, named NYUGI and PIVO VÁR are located in the city centre, and they both have an indoor bar as well as an open-air beer garden (Fig. 1). The areas of the beer gardens of NYUGI and PIVO VÁR are about 330 m<sup>2</sup> and 125 m<sup>2</sup>, respectively. The beer garden of the former is covered by grass and

crushed gravel, and shaded by the surrounding trees. The beer garden of PIVO VÁR, enclosed by buildings and a firewall, is covered by light-coloured paving stones. In this tavern only artificial shading is provided. In the beer garden of NYUGI there are 9 benches with a seating capacity of at least 8 people on each bench, while the other beer garden is equipped with 10 round tables with 4 seats for each (Fig. 2, Table 1).



Fig. 2 Photographs of the two investigated taverns: NYUGI (A) and PIVO VÁR (B)

Table 1 Features of the two investigated beer gardens

	NYUGI	PIVO VÁR
<b>Area</b>	330 m <sup>2</sup>	125 m <sup>2</sup>
<b>Open-air seats</b>	9 benches	10 tables
<b>Capacity</b>	about 72 people	about 40 people
<b>Ground coverage</b>	grasses, crushed gravel, trees	paving stone
<b>Shading</b>	surrounded by trees, artificial shading	artificial shading

## 2.2. Method

The current human bioclimatological studies require complex methods, *i.e.* the investigation of the thermal comfort by means of objective and subjective approaches (Nikolopoulou and Steemers 2003, Thorsson et al. 2004, Knez and Thorsson 2006, Nikolopoulou and Lykoudis 2006). The objective method used in our study is based on human thermal comfort index calculation from a set of meteorological variables measured in regular intervals. As a subjective method an investigation of human attitude was carried out. The attendance of the two taverns was observed in the afternoon hours (12–3 p.m.) within the frame of a 6-week long systematic study. The study was conducted between April 8<sup>th</sup> and May 15<sup>th</sup> 2008, as weather conditions by this period of the year became comfortable enough for outdoor activities, while the sudden change of the thermal sensation could still strongly influence human behaviour.

### 2.2.1. Objective method

As an objective measure of the thermal comfort sensation, a widely used biometeorological index, PMV (Predicted Mean Vote) was selected. Fanger (1972) derived this indicator from an indoor-use comfort model based on his investigations on the thermal comfort of over 1000 people in an artificial climate chamber, where several climate parameters as well as human clothing and activity could independently be varied (Höppe



1993). PMV predicts how a large sample of human beings would characterise their comfort sensation according to the meteorological environment, the level of their activity and their clothing using the values of the originally seven-point (from -3 to +3) ASHRAE comfort scale. This comfort scale at around 0 is characterized as comfortable, higher and lower values indicate increasing probability of thermal discomfort as well as stress due to heat and cold conditions, respectively. In (extreme) real weather conditions, PMV can be higher than +3 or lower than -3 (Mayer and Höppe 1987) (Fig. 3).

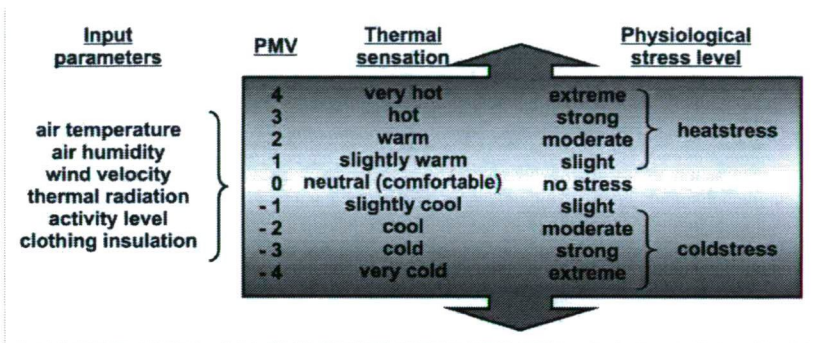


Fig. 3 Input parameters for the calculation of PMV (Predicted Mean Vote) and the PMV ranges for different human thermal sensations and stress levels

As a first step to calculate the PMV values, the actual weather conditions (air temperature, relative humidity, wind velocity, and global radiation) were recorded in 10-minute intervals by a QLC 50 type automatic climate station. The air temperature and the air humidity values were observed in a Stevenson screen about 200 m from the study area. Wind velocity and global radiation were measured on the roof of a university building next to the study area (Fig. 1B). Using these measured parameters as input, comfort index PMV was calculated by means of a computational comfort model, RayMan, developed according to the guideline 3787 of the German Engineering Society (VDI 1998, Matzarakis et al. 2007). To follow the sampling frequency of the subjective method detailed below, 30-minute averages of PMV (between 12 and 3 p.m.) were calculated within each daily monitoring period. The averages of the PMV values of each daily period were also determined (later referred to as 'daily mean PMV value').

### 2.2.2. Subjective method

The subjective method considered the relative attendance of the taverns an indicator for the subjective human thermal comfort sensation. The observations were carried out every Tuesday, Wednesday, and Thursday in the 6-week long measuring period, because these days provided samples of sufficiently high number of visitors for the analysis. (This fact can be explained by the weekly routine of the guests from the nearby university building.)

Between 12 and 3 p.m., the number of guests in the beer garden and the indoor part of each tavern were recorded in 30-minute intervals (i.e. 7 times a measurement day). For each daily monitoring period, the recorded number of guests sitting indoors and outdoors was summed up separately. Relative attendance of the indoor and outdoor parts over the

daily monitoring period (referred later as ‘daily relative attendance’) were calculated from these sums by dividing the number of guests sitting in the corresponding place by the total number of guests (guests sitting indoors + guests sitting outdoors).

### 3. RESULTS AND DISCUSSION

In the first part of the 6-week long monitoring period, guests rather preferred the indoor sites (especially in the tavern PIVO VÁR), but an opposite tendency can be observed by the end of the period (Fig. 4), obviously in connection with the warming weather. However, the figure clearly shows that the absolute (total) attendance, in the case of both taverns, was also strongly influenced by external factors. Therefore, daily relative attendances had to be calculated in order to construct an attendance index independent from the total number of visitors and thus ensure the comparability of the monitoring days.

It is important to note that relative attendances were not normalized by the number of seats since the capacities of the taverns were found to be rather flexible: the staff readily placed new benches in the beer gardens if no free seat seemed to be available or the guests made room for the newly arrived ones. So it can be assumed that the visitors could freely decide where to take seat according to their thermal comfort sensation. However, this hypothesis is expected to be adequate only in the early and late seasons (April–May and September–October). Figs. 5 and 6 show the daily mean PMV values and relative attendances of the indoor and outdoor places for each measurement of the monitoring period.

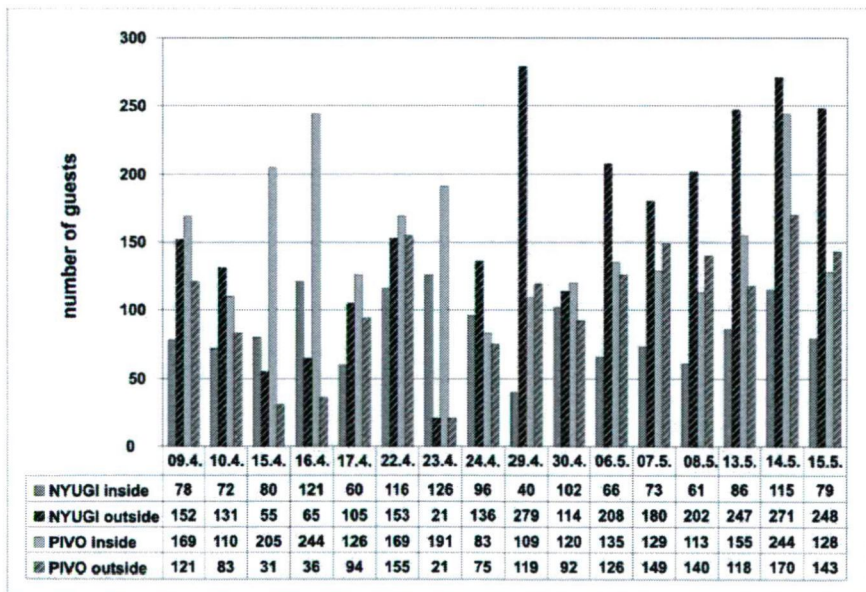


Fig. 4 Number of guests sitting indoors and outdoors in the two taverns, summed up over the daily monitoring periods (April–May 2008)



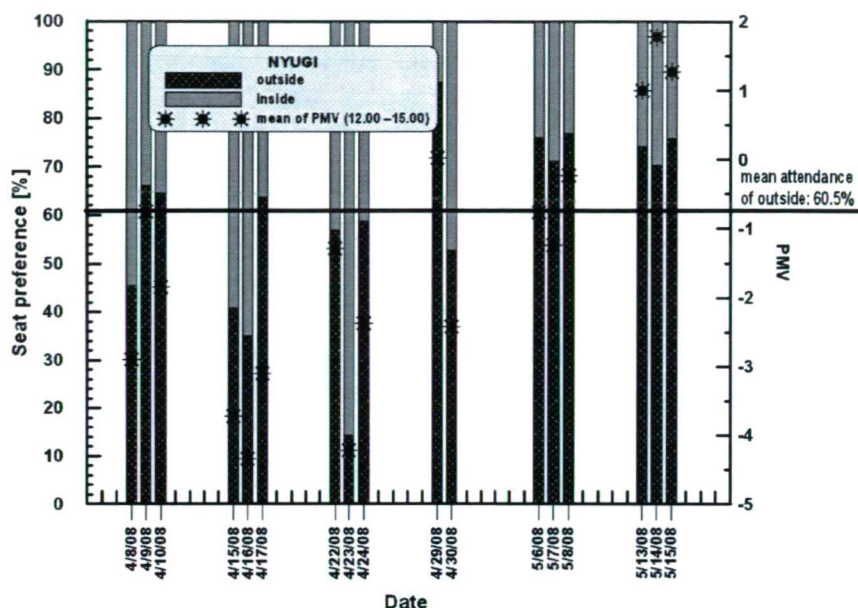


Fig. 5 Daily mean PMV values (12.00–3.00 p.m.) and relative attendance of the indoor and outdoor places in the tavern NYUGI

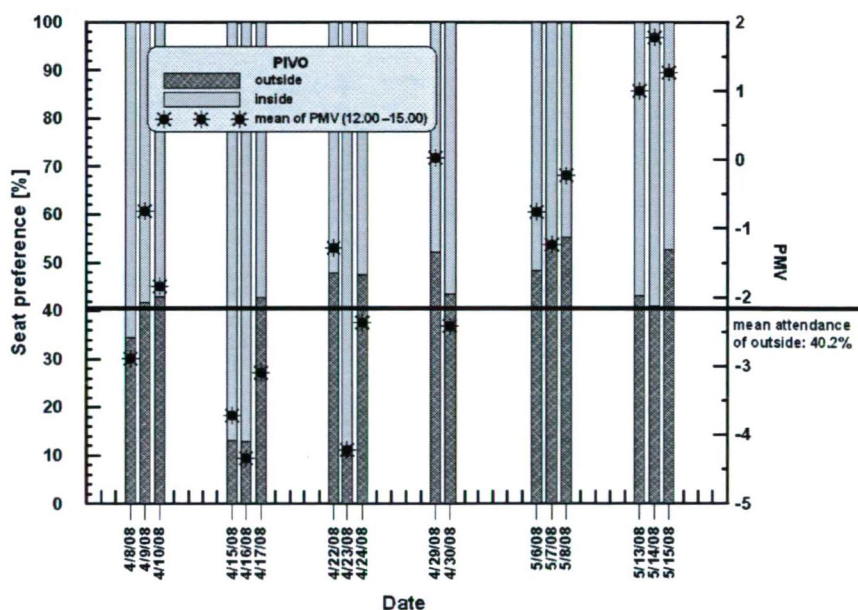


Fig. 6 Daily mean PMV values (12.00–3.00 p.m.) and relative attendances of the indoor and outdoor places in the tavern PIVO VÁR

In the tavern NYUGI, 60.5% of the guests in average preferred to take seat outdoors over the whole monitoring period. However, on three days (15, 16 and 23 April) the relative attendance of the beer garden dropped below 50% (referring to the preference of indoor sites), which can be explained by the weather conditions. On these days heavy rains prevailed accompanied with significantly worsened thermal conditions and the benches remained wet in the rainless hours too. It should also be emphasized that in this tavern the relative attendances varied in accordance with the variation of the mean PMV values, except for the last week of May, when the PMV values increased above 1 (which refers to a slight heat stress) while the daily percentage of the outdoor seat preference did not increase compared to the previous week.

In the tavern PIVO VÁR, the preference of outdoor seats on the three rainy days in April showed the same decline as mentioned above. However, only 40.2% of the guests in average preferred the beer garden to the indoor place over the whole period. In addition, less obvious correlation can be found between the seat preference and the PMV values: the relative attendance of the outdoor place increased only up to a certain level with the improvement of the thermal conditions. Consequently, the guests proved to be less sensitive to the thermal load in the tavern PIVO VÁR.

In order to explain the observed differences in the relation between the seat preference and the PMV values (*i.e.* the thermal conditions), the surface coverage of the places should be taken into account. The ground of the tavern NYUGI is almost completely covered with grass and several deciduous trees shade the tables (Fig. 2A). This environment is closer to a natural state and results in cooler microclimatic conditions, which remain enjoyable for the guests even under slightly increased thermal stress. On the contrary, the beer garden of the tavern PIVO VÁR has no vegetation and is covered by light cobblestones which increase the irradiative load on the human body due to the increased rate of reflected shortwave radiation (Fig. 2B). In addition, this place is enclosed by a firewall and buildings and this construction heavily restricts the air flow, which could otherwise moderate the heat flow.

Fig. 7 shows the daily relative attendances of the outdoor places as the function of the daily mean PMV values for the two taverns. As detailed above, an increasing relative attendance of the outdoor places could be observed up to a certain PMV value (this was especially apparent in case of the tavern PIVO VÁR). Above this level, the guests increasingly preferred the indoor areas to the beer gardens. This tendency exhibiting a maximum suggested that the plotted data pairs of daily relative attendance and mean PMV could be fitted by a quadratic function. Our assumption was confirmed by the coefficients of determination  $R^2$ , found to be 0.82 and 0.86 for the quadratic fittings in case of the taverns NYUGI and PIVO VÁR, respectively. Through this mathematical operation, the maxima of the fitted functions provide objective thresholds of PMV for each catering place, which can be considered as the comfort limits above which the intensified heat stress makes the guests prefer the indoor parts with increasing probability.

As expected from the analysis of the relative attendances of the indoor and outdoor places above, the maxima of the fitted functions provided different PMV thresholds for the two taverns:  $PMV = 0.56$  was found for NYUGI (tavern with a more natural environment) and  $PMV = -0.29$  for PIVO VÁR (tavern with a rather artificial environment).

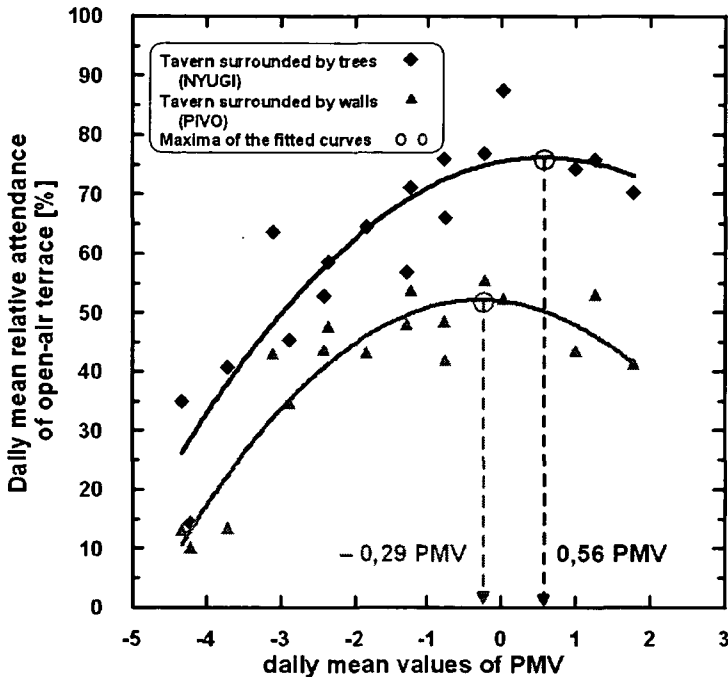


Fig. 7 Daily relative attendances of the outdoor places of taverns NYUGI and PIVO VÁR as the function of the daily mean PMV values

#### 4. CONCLUSIONS

This study investigated the attendance of two neighbouring taverns (NYUGI, PIVO VÁR) in the city centre of Szeged (Hungary) and the attitude of their guests under varying thermal conditions by subjective and objective methods. The latter comprised the bioclimatological index PMV, while the preference of the open-air seats was measured by the relative attendance of the outdoor places on selected days.

The results of our observations showed that the degree of utilisation of outdoor places and its dependence on the thermal conditions are strongly affected by the design of the open-air places. The quantitative analysis revealed that the preference of outdoor places generally increases with warming thermal conditions up to a certain PMV value, then it decreases due to the intensified heat stress. However, the PMV values corresponding to the maximum of the fitted relative attendance vs. mean PMV functions proved to be characteristic of the design of the individual places. Since the tendencies found are in harmony with common human behaviour, at the same time they confirmed the correctness of the applied comfort index. The study revealed that the visitors preferred the more natural outdoor environment (NYUGI) compared to the rather artificial one (PIVO VÁR). The analysis also showed that the guests tolerated the heat stress in the more natural environment better than in the artificial location.



Similar investigations should be extended to other catering places, sites for outdoor entertainment and open-air public spaces in order to get a more accurate picture of the relationship between the thermal conditions and the attendance of public places in urban environments. The results of such studies should provide useful information

(i) for designers of public places (recreational areas such as parks, playgrounds and outdoor places of cafes, restaurants etc.) how to develop the attraction of these places to increase their attendance, and

(ii) for organizers of outdoor occasions (concerts, sport and cultural events, fairs etc.) to select the most appropriate date and time for such events.

**Acknowledgements** – The study was supported by the Hungarian Scientific Research Fund (OTKA K-67626). The authors' special thank to E. Csutor and M. Venter for taking part in the subjective survey and to László Égerházi and Eszter Tanács for the language revision of the manuscript.

## REFERENCES

- Fanger PO (1972) Thermal Comfort. McGraw – Hill Book Co., New York
- Gulyás Á, Unger J, Matzarakis A (2006) Assessment of the microclimatic and human comfort conditions in a complex urban environment: Modelling and measurements. *Build Environ* 41:1713-1722
- Höppe P (1993) Heat balance modelling. *Experientia* 49:741-746
- Jendritzky G (1993) The atmospheric environment – an introduction. *Experientia* 49:733-740
- Katzschner L (2007) Microclimatic thermal comfort analysis in cities for urban planning and open place design. In: Mayer H (ed) *Berichte des Meteorologischen Instituts der Albert-Ludwigs Universität Freiburg*, Nr. 16, 31-36
- Knez I, Thorsson S (2006) Influences of culture and environmental attitude on thermal, emotional and perceptual evaluations of a public square. *Int J Biometeorol* 50:258-268
- Mayer H, Höppe P (1987) Thermal comfort of man in different urban environments. *Theor Appl Climatol* 38:43-49
- Matzarakis A, Mayer H (1996) Another kind of environmental stress: thermal stress. *WHO Newsletter* 18:7-10
- Matzarakis A, Rutz F, Mayer H (2007) Modelling radiation fluxes in simple and complex environments – application of the RayMan model. *Int J Biometeorol* 51:323-334
- Nikolopoulou M, Lykoudis S (2006) Thermal comfort in outdoor urban spaces: Analysis across different European countries. *Build Environ* 41:1455-1470
- Nikolopoulou M, Steemers K (2003) Thermal comfort and psychological adaptation as a guide for designing urban places. *Energy Build* 35:95-101
- Unger J (1999) Comparisons of urban and rural bioclimatological conditions in the case of a Central-European city. *Int J Biometeorol* 43:139-144
- Unger J (2006) Modelling of the annual mean maximum urban heat island with the application of 2 and 3D surface parameters. *Climate Res* 30:215-226
- Unger J, Sümeghy Z, Zoboki J (2001) Temperature cross-section features in an urban area. *Atmos Res* 58:117-127
- Thorsson S, Lindqvist M, Lindqvist S (2004) Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. *Int J Biometeorol* 48:149-156
- VDI (1998) VDI guideline 3787, Part 1: Environmental Meteorology, Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning. Beuth, Berlin. 29 p